PD-0142

Efficient daily linac QA of MLC, block and dose using EPID images of warm-up fields

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Purpose/Objective: An efficient and comprehensive tool for daily QA of the linac was developed based on EPID images. The objective was a routine procedure that
1) Makes clinical use of the daily linac warm-up time
2) Reliably checks the EPID, MLC, block and dose output
3) Is independent of the type of linac- or EPID
4) Provides warnings when out of tolerance
5) Allows sufficient error analysis and time trend detection
6) Can be easily measured and analysed by RTTs
7) No phantom needed
8) Takes < 15 minutes

Materials and Methods: The Daily Linac QA tool was developed in Matlab. EPID images are acquired of the 14 fields irradiated during warm-up of the linac. The images are then automatically analysed, beginning with a check of the EPID, followed by geometric tests of the block and MLC, finishing with measurements of the dose output. The tool was configured to immediately present results to the user (RTT), with a conclusion whether or not the linac can be used to treat patients.

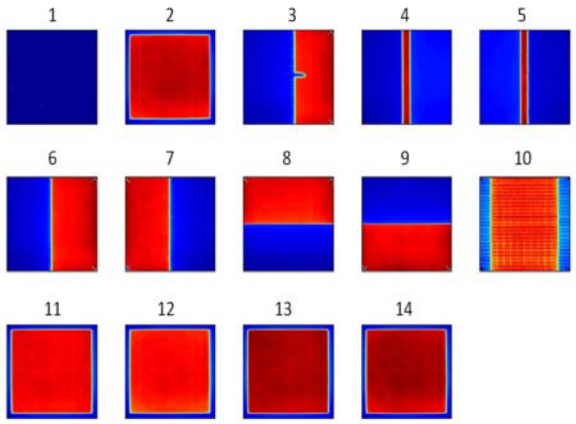

Figure 1: Overview of all acquired fields : (1) dark current (2) 24x24 cm, col 90° (3) leaf-identification image (4) leaf-bank A opposite block (5) leaf-bank B opposite block (6) half-field leaf-bank A (7) half-field leaf-bank B (8) half-field block A (9) half-field block B (10) 10-segment picket fence test (11) 24x24 cm, 2x4 MU, 6 MV (12) 24x24 cm, 2x4 MU, 10 MV (13) 24x24 cm, 50 MU, 6 MV and (14) 24x24 cm, 50 MU, 10 MV.

Results: The Daily Linac QA tool takes 15 minutes and is performed by RTTs on each linac during warm-up. Warnings are automatically sent to physicists when tolerances are exceeded. An overview of the resulting test analysis is presented in the table below.

Test	images used	Analysis description	Tolerance
EPID dark current	1	central-axis grey-level without irradiation	-
EPID sagging	6,7,8,9	comparison of EPID centre with constructed beam centre	2 mm
Leaf positions	3	EPID pixel rows of leaf centres + determining 'ref. leaf'	-
Leaf minor bank A&B	4/5	gap between leaves and opposing block, rel. to the ref. leaf	0.75 mm
Leaf-bank offset Block offset	6,7 8,9	over-/undershoot in profile of summed half-fields	7.5 %
Block-limited field size Leaf-limited field size	2 14	Field size from horizontal profile of 24x24cm field	1.5 mm
Picket fence test	10	largest over-/undershoot for all leaves and all abutting segments	11 %
Collimator rotation	8	field-edge angle of half-field	0.5°
for 6 / 10 MV			
Absolute dose	13/14	*consistency* of EPID grey-level for fixed-MU field	2 %
Proportionality	11,13/12,14	ratio of central-axis grey-level of 2x4 MU /50 MU	3 %
Dose-rate	11/12	*consistency* of central-axis grey-level of single EPID frame	7.5 %
Flatness	13/14	*consistency* of grey-level-distribution rel. to beam centre	2 %
Flatness low-MU	11,13/12,14	grey-level distribution of 2x4 MU rel. to 50 MU field	2 %

Conclusions: The Daily Linac QA tool meets all the objectives in terms of reliability, independance, safety, detection, simplicity and efficiency. The tool has been used clinically in our hospital for 3 years with great success, and has proved to be a valuable aid to identify points of attention for linac maintenance.

PD-0143

4D cone-beam computed tomography combining total variation regularization and motion compensation

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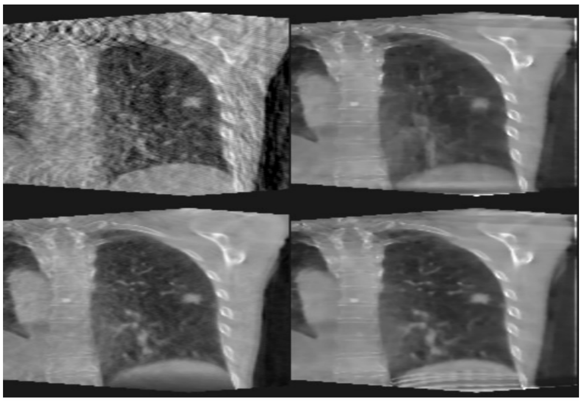
Purpose/Objective: Breathing motion affects the image guidance of lung tumors when projection images are acquired using a slowly rotating cone-beam (CB) CT X-ray system while the patient breathes. Advanced methods have been developed to achieve streak-free and blur-free reconstructions, most of which are either based on motion compensation, or on regularization using some a-priori information.
This paper introduces a method that combines both approaches, called Motion Compensated RecOnstructiOn using Spatial and Temporal Regularization (MC ROOSTER), and describes how it compares with its regularization-only counterpart (ROOSTER), with Motion Compensated FDK (MC FDK), and with respiration-correlated FDK.
Materials and Methods: ROOSTER is a 4D reconstruction algorithm that alternates between several optimization goals: forward and back projections to match the measured projection data, positivity enforcement, restriction of motion to a motion mask, spatial Total Variation (TV) denoising, and temporal TV denoising.
A 4D Deformation Vector Field (DVF) can be extracted from the 4D planning CT, and used to improve the reconstruction. MC ROOSTER takes advantage of this 4D DVF by performing the temporal TV denoising on warped volumes. All

reconstruction algorithms have been implemented using 'The Reconstruction ToolKit' (RTK), an open source C++ library based on 'The Insight ToolKit' (ITK).
Results: Data from a patient admitted for lung cancer and imaged with the Elekta Synergy cone-beam CT has been reconstructed with all four reconstruction methods. The figure shows a coronal slice extracted from each of the volumes.



Coronal slice of a patient admitted for lung cancer. Top left: respiratory-correlated FDK. Top right: 4D ROOSTER. Bottom left: motion-compensated FDK. Bottom right: MC ROOSTER

Conclusions: With a good motion estimation, MC ROOSTER yields results similar to those of MC FDK. However, it can be used with an imperfect DVF, and MC ROOSTER reconstructions can exhibit a motion different from that of the DVF. When the DVF extracted from the planning CT cannot be assumed to be correct, yet is supposed to be more relevant than a null DVF, MC ROOSTER can take advantage of it while still allowing residual motion.

PD-0144

Classification of tumor sub-volumes based on Dynamic Contrast Enhanced MRI model hierarchy for cervical cancer

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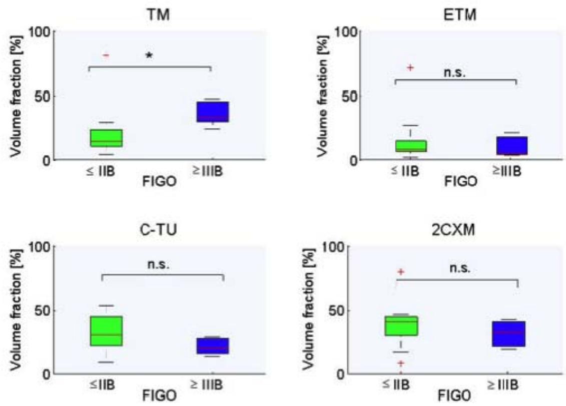
Purpose/Objective: Heterogeneous uptake of contrast agent during Dynamic Contrast Enhanced – MRI experiments is often found in patients with locally advanced cervical cancer. The information obtained from the heterogeneous enhancement within the tumor is likely to reflect distinct domains of different underlying tissue characteristics. The hierarchical structure of a set of kinetic models may be based on the general 2-Compartment eXchange Model (2CXM). Under limiting condition this generic model may be simplified to the Tofts model (TM) (weakly vascularized), the Extended Tofts model (ETM) (highly perfused) and the Compartmental Tissue-Uptake model (C-TU) (uptake regime). The aim of this study was to evaluate the ability of a set of nested kinetic models to classify sub-volumes within cervix cancer tumor tissue. The correlation of model selection to tumor stage was investigated.

Materials and Methods: In brief, 15 cervical cancer patients with advanced stages (FIGO: IIA/IIB/IIIB/IVA – 1/9/4/1) underwent DCE-MRI prior to radiotherapy. DCE-MRI was performed using a 3T Philips Achieva scanner and a three-dimensional (3D) saturation recovery spoiled gradient echo technique with 20–24 slices having a 5 mm slice thickness, TR/TE of 2.9/1.4 ms, Tsat of 25ms, flip angle (FA) of 10°, in-plane resolution 2.3 mm x 2.3 mm and 2.1 s time resolution. The bolus injected was 0.1 mmol/kg Dotarem at 4 ml/s, followed by a 50 ml saline flush. A total of 120 dynamic scans were obtained of which 18 time-points were scanned before the bolus arrived at the iliac arteries. A T1 relaxation map was constructed before contrast injection. The nested set of kinetic models included 2CXM, C-TU, ETM and TM. The model which described best the temporal contrast agent concentration profile (i.e. best fit) was identified using the corrected Akaike Information Criteria. For the kinetic analysis a population based input function using a similar injection profile was applied. For statistical inference a one sided non-parametric Wilcoxon rank-sum test was employed with the significance level of $p<0.05$.
Results:



The main observation was the ability of the hierarchical tracer kinetic model sub-volume classification to detect distinct contiguous regions within the tumor. The division of the tumors into the nested set of kinetic model, measured by median and interquartile range (IQR) of volume fraction were; TM: 23.4% (12.4% - 32.4%), ETM: 7. 4% (4.6% - 16.4%), C-TU: 27.9% (17.6% - 37.9%) and 2CXM: 40.5% (24.6% 43.0%). There was a significant difference ($p=0.01$) in the percentage volume best described by TM between patients with tumor stage ≤IIB (10 pts) and tumor stage ≥IIIB (5 pts) (Fig. 1.). The volume fractions described by the remaining models were not found to differ significantly between the stage groups.
Conclusions: Firstly, we found that the hierarchical kinetic classification approach was able to identify contiguous regions within tumor tissue in patients with locally advanced cervical cancer. Secondly, it was seen that patients with the most advanced stages (≥IIIB) tended to be overly expressing regions of TM DCE-MRI enhancement profiles.

PD-0145

Diffusional kurtosis as a biomarker of prostate cancer response to radiation therapy

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